difference can only be answered when objective evaluation techniques are available to test computer programs and electrocardiographers. Such methods are being developed in our department as well as in several others outside Canada.

However, cardiologists do not have to wait until these issues are resolved to make profitable use of the computer. We have identified two classifications, normal sinus rhythm and normal ECG contour, for which there was general agreement between computer and all the electrocardiographers. Such classifications may apply to nearly 30% of our hospital population, though the percentage may well be higher in centres not as heavily oriented towards tertiary care as is our centre. Our results indicate that ECGs classified by the computer as normal with respect to rhythm and contour do not require review by an electrocardiographer since significant alterations by the latter are rare. Instead, review by a technician to safeguard against obvious computer errors in pattern recognition should be sufficient.

Under these circumstances it is economically feasible for electrocardiographers to use the computer for ECG interpretation, provided a sufficiently large number of ECGs are being processed. This is true especially if the benefits the computer will provide in storage and retrieval of old ECG interpretations are considered. An improvement in the accuracy of ECG interpretation by use of the computer will then be an additional benefit, once it has been demonstrated convincingly.

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References

1. *Automated Electrocardiography in the United States*, prepared by Arthur D. Little, Inc., Cambridge, MA under contract 230-75-0212 for division of health care information systems and technology, health resources administration, National Centre for Health Services Research, Washington, 1976
2. BONNER RE, CREVASSE L, FERRER MI, et al: A new computer program for analysis of scalar electrocardiograms. *Comput Biomed Res* 5: 629, 1972
3. WEIHRER AL, WHITEMAN JR, ZIMMERMAN A, et al: Computer programs for an automated electrocardiographic system, in *Clinical Electrocardiography and Computers*, CACERES CA, DREIFUS LS (eds), New York, Acad Pr, 1970, p 83
4. CORNFIELD J, DUNN RA, BATCHLOR CD, et al: Multigroup diagnosis of electrocardiograms. *Comput Biomed Res* 6: 97, 1973
5. HU K, FRANCIS DB, GAU GT, et al: Development and performance of Mayo–IBM electrocardiographic computer analysis program (V70). *Mayo Clin Proc* 48: 260, 1973
6. WARTAK J, MILLIKEN JA, KARCHMAR J: Computer program for diagnostic evaluation of electrocardiograms. *Comput Biomed Res* 4: 225, 1971
7. *The Computer-Assisted ECG From Laboratory to Community — a Report of the Denver Demonstration*, DHEW publ no (HRA) 74-3104, US Public Health Service, health resources administration, Rockville, MD, 1973
8. PIPBERGER HV, MCCAUGHAN D, LITTMANN D, et al: Clinical application of a second generation electrocardiographic computer program. *Am J Cardiol* 35: 597, 1975
9. CREVASSE L, ARIET M: A new scalar electrocardiographic computer program. *JAMA* 226: 1089, 1973
10. SIMONSON E, TUKA N, OKAMOTO N, et al: Diagnostic accuracy of the vectorcardiogram and electrocardiogram. A cooperative study. *Am J Cardiol* 17: 829, 1966
11. GREGOR RD, WOLF HK, HARRIS LK: Effect of computer assistance on the performance of human electrocardiogram interpreters. *Ann R Coll Physician Surg Can* 10: 36, 1977
12. WOLF HK, MACINNIS PJ, STOCK S, et al: Computer analysis of rest and exercise electrocardiograms. *Comput Biomed Res* 5: 329, 1972
13. WOLF HK, GRAYSTONE P, LYWOOD DW, et al: Suggested minimum specifications for data acquisition instrumentation in computer-assisted ECG processing systems. *J Electrocardiol* 9: 239, 1976

Survival of patients treated for end-stage renal disease by dialysis and transplantation

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The results of treatment in 213 patients with end-stage renal disease who underwent hemodialysis, peritoneal dialysis or transplantation, or a combination, between 1962 and 1975 were analysed. Comparison by censored survival analysis showed significantly better ($P < 0.01$) patient survival with the integrated therapy of dialysis and transplantation than with either form of dialysis alone. There was no significant difference in survival of males and females but survival at the extremes of age was poorer. Analysis of survival by major cause of renal failure indicated best survival in patients with congenital renal disease. Graft and patient survival rates at 1 year after the first transplantation were 42% and 69%. The major cause of death in this series was vascular disease but infection was responsible for 50% of deaths after transplantation. While integration of dialysis with transplantation produces best patient survival, this course is possible only when sufficient cadaver kidneys are available.

On a analysé les résultats du traitement chez 213 patients souffrant de maladie rénale au stade terminal qui ont subi, entre 1962 et 1975, l'hémodialyse, la dialyse péritonéale ou la greffe, ou une combinaison. La comparaison, par analyse pondérée de la survie, a révélé une survie significativement meilleure ($P < 0.01$) pour le traitement comprenant dialyse et greffe que pour l'une ou l'autre des deux formes de dialyse employées seules. On n'a observé aucune différence significative entre les taux de survie des hommes et des femmes, mais la survie était moins bonne aux limites de l'intervalle d'âge. L'analyse de la survie pour les principales causes d'insuffisance rénale a indiqué une meilleure survie chez les patients souffrant de maladie rénale congénitale. Les taux de survie à 1 an pour les greffes et pour les patients après la première greffe ont été de 42% et de 69%, respectivement. La principale cause du décès dans ce groupe a été les maladies vasculaires mais l'infection compte pour 50% des causes de décès après une greffe. Alors que l'association de la dialyse et de la greffe donne la meilleure survie, ce mode de traitement n'est possible que quand on dispose d'une nombre suffisant de reins d'origine cadavérique.

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During the last 25 years dialysis and transplantation for end-stage renal disease have developed to the extent that rehabilitation is regarded as a more acceptable criterion of successful treatment than patient survival. While economic concerns may be responsible for this change in emphasis, patient sur-

vival remains of fundamental importance. Survival data also provide a way to compare different modalities of treatment for chronic renal failure and serve as a guide for future planning.

This paper describes the experience of one unit in the treatment of patients with end-stage renal disease over a 12-year period by hemodialysis, peritoneal dialysis or transplantation, or a combination of these.

Patients and methods

A dialysis centre for the care of patients with acute or chronic renal failure was established in 1962 at the University of Alberta Hospital. Transplantation was first performed in Edmonton in 1967 and home dialysis was initiated in 1970.

Between December 1962 and April 1975, 213 patients were treated for end-stage renal disease by hemodialysis, peritoneal dialysis or transplantation, or a combination of these modalities, and it is the results of treatment in these patients that form the subject of this study.

Original disease, age, sex and duration of different modes of therapy were determined from clinical charts. Causes of death were analysed according to age, sex, original disease and mode of therapy at the time of death. After the data had been coded, basic descriptive statistics were produced and comparisons made by tests of analysis of variance.[1] Censored survival curves were compared by a modification of the Wilcoxon test.[2]

In the early years of the program patients were accepted if they had no evidence of other diseases that would hinder rehabilitation and decrease life expectancy.[3] Since then acceptance criteria have been broadened and the only patients now excluded from the program are those with incapacitating pulmonary or cardiovascular disease, terminal malignant disease or psychosis not due to uremia. As in many other centres, however, we have been reluctant to accept persons with diabetes for maintenance therapy because of their severe vascular disease. No patient treated for end-stage renal disease during the 12 years was excluded from this study, even when death occurred within a few days of the initiation of treatment.

Results

Of the 213 patients treated since 1962, 100 were still alive in April 1975; 55 had been treated by hemodialysis alone and 25 by peritoneal dialysis alone, 2 had received transplants without previous dialysis and 131 (62%) had been treated by a combination of modes of therapy. Yearly numbers of admissions to the program with rates of transplantation and transfer to home dialysis are shown in Fig. 1. Mean age on admission to the program was 29 years for the 131 males and 34 years for the 82 females. Analysis of patient age at year of admission to the program indicated the more liberal acceptance criteria used in later years in that persons under the age of 10 years or over the age of 60 years were not admitted for treatment until after 1968.

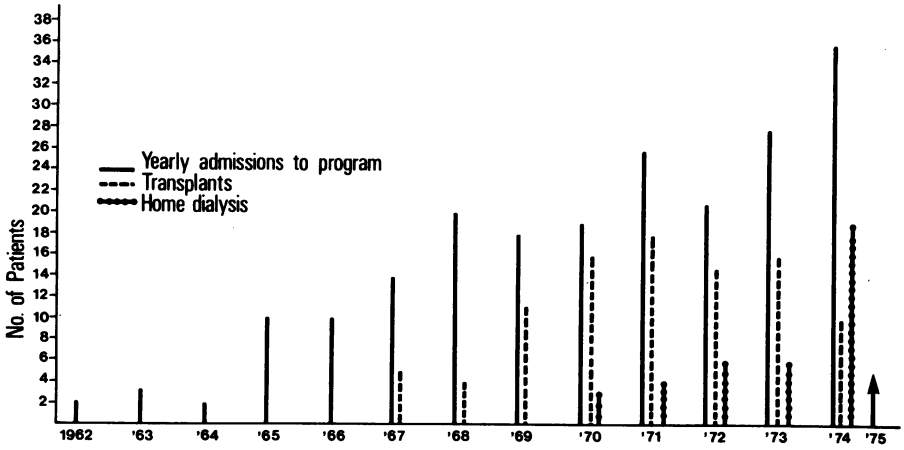

FIG. 1—Comparison of yearly number of patients with end-stage renal disease accepted for treatment and number receiving a transplant or being transferred to home dialysis.

Table I—Primary cause of renal failure in 213 patients

Cause	No. (and %) of patients
Glomerulonephritis	99 (47)
Chronic, advanced	60
Membranous	3
Membranoproliferative	19
Rapidly progressive	12
Proliferative, other	1
Poststreptococcal	3
Other	1
Interstitial	25 (12)
Pyelonephritis	18
Tuberculosis	1
Gout	2
Nephrocalcinosis	2
Renal lithiasis	2
Systemic	6 (3)
Amyloidosis	3
Lupus erythematosus	2
Postpartum nephropathy	1
Toxic	9 (4)
Analgesic abuse	8
Antibiotic abuse	1
Congenital and familial	35 (16)
Polycystic disease	16
Microcystic disease	3
Alport's syndrome	3
Congenital renal hypoplasia	1
Bladder neck obstruction	4
Other hereditary nephropathies	2
Other congenital nephropathies	6
Hypertension	28 (13)
Diabetes	4 (2)
Other	7 (3)
Trauma	1
Oxalosis	1
Scleroderma	1
Myeloma	1
Unknown	3

The diseases responsible for renal failure in these patients are listed in Table I. Biopsy confirmation of disease was obtained in 28% of patients.

Survival of patients according to mode of therapy is illustrated in Fig. 2. Survival was significantly better ($P < 0.01$) in patients treated by dialysis and transplantation than in those treated by either form of dialysis alone at 6, 12, 24 and 36 months, and in patients treated by hemodialysis alone than in those treated by peritoneal dialysis alone at 6, 12 and 24 months.

Mean survival according to age at initiation of therapy is shown in Table II. Survival of patients under the age of 10 years was significantly less ($P < 0.05$) than that of patients aged 10 to 19 years, but further statistical distinctions were limited by the small number of patients (four) in this group. Survival of patients 60 years of age or older

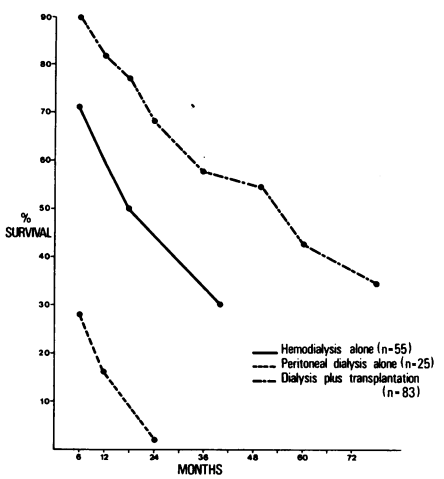

FIG. 2—Survival of patients treated by hemodialysis alone, peritoneal dialysis alone, or dialysis and transplantation.

Table II—Patient survival according to age at initiation of therapy for end-stage renal disease

Age (yr)	n	Survival (mo) Mean	Standard deviation	Range
1–9	4	11.0	5.6	1–18
10–19	22	30.8*	22.7	1–78
20–29	46	15.9	34.9	1–146
30–39	42	29.7	32.3	1–95
40–49	54	22.4	22.7	1–78
50–59	31	17.7	13.4	1–50
60 +	14	8.2†	6.7	1–15

*Significantly better ($P < 0.05$) than at ages 1 to 9.
†Significantly less ($P < 0.01$) than at ages 10 to 19, 20 to 29, 30 to 39 and 50 to 59.

Table III—Causes of death and mode of therapy at the time of death in patients treated for end-stage renal disease

Cause of death	No. (and %) of patients	Therapy at time of death; no. of patients: Hemodialysis	Peritoneal dialysis	Had received transplant
Cardiovascular	47 (42)	28	11	8
Myocardial ischemia	6			
Hyperkalemia	6			
Pericarditis	2			
Cardiac failure	8			
Cardiac arrest (cause unknown)	15			
Hypertension	2			
Pulmonary embolism	2			
Cerebrovascular accident	6			
Hemorrhage	7 (6)	4	1	2
Gastrointestinal	2			
Other	5			
Infection	32 (28)	7	10	15
Pulmonary				
Bacterial	5			
Viral	3			
Fungal	2			
Septicemia	9			
Hepatitis	1			
Peritonitis	7			
Other	5			
Social	3 (3)	2	1	—
Patient refused therapy	1			
Therapy discontinued for other reasons	2			
Other	24 (21)	11	2	5
Uremia	3			
Pancreatitis	1			
Malignant disease				
Immunosuppressive therapy	1			
Other	2			
Perforated ulcer	1			
Disseminated lupus erythematosus	1			
Inhalation of vomitus	1			
Air embolism	1			
Encephalopathy	1			
Unknown	12*			

*Includes six patients whose therapy at the time of death was known and six patients who were lost to follow-up.

Table IV—Details of renal transplantation in 85 patients

Transplant no.	No. of transplants	Source and no. of grafted kidneys: Cadaver	Living parent	Living sibling	Living donor, other
1	85	71	9	4	1
2	13	12	1	—	—
3	2	2	—	—	—
4	1	1	—	—	—
Total no.	101	86	10	4	1

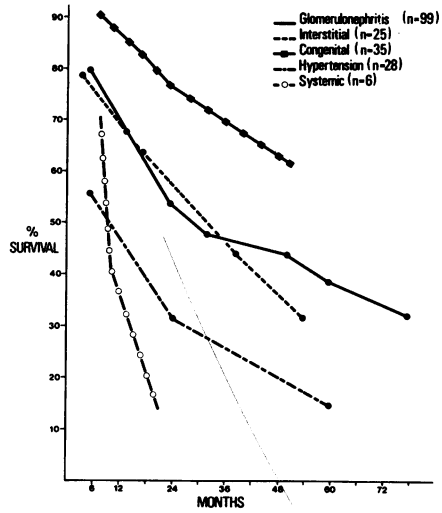

FIG. 3—Survival of patients according to major causes of renal failure.

was significantly less ($P < 0.01$) than that of patients in the other age groups except 1 to 9 and 40 to 49 years.

The association between survival and major causes of renal failure in this series is shown in Fig. 3. Not unexpectedly, patients with systemic disease had the lowest survival rate, although there were only six patients in this group. Hypertension was also associated with poor survival partly because hypertension as a cause of end-stage renal disease was more common in older patients; in 6 (43%) of the 14 patients 60 years of age or older hypertension was the cause of renal failure. Survival was significantly better ($P < 0.05$) at 6, 12, 24, 36 and 48 months in the group of patients with congenital renal disease than in any other group. Congenital diseases were the cause of renal failure in two main age groups: 50% of patients aged 10 to 19 years had a rare hereditary nephropathy or anatomic abnormality, and polycystic disease was an important cause in patients aged 40 to 49 years.

At the conclusion of the study 113 patients were dead. The causes of death and modes of therapy at the time of death are shown in Table III. Vascular disease was the main cause of death in dialysis patients. Infection was responsible for 50% of the deaths in patients who died after transplantation and for 40% of the deaths in patients treated by peritoneal dialysis, many of which were due to peritonitis or septicemia associated with peritonitis. Maintenance peritoneal dialysis is now rarely used in this region except when home or medical circumstances prohibit the use of hemodialysis.

Between 1967 and April 1975, 101 transplants were received by 85 patients, as detailed in Table IV. Of the 85 patients 2 received transplants without previous dialysis. Because so few transplantations from living donors

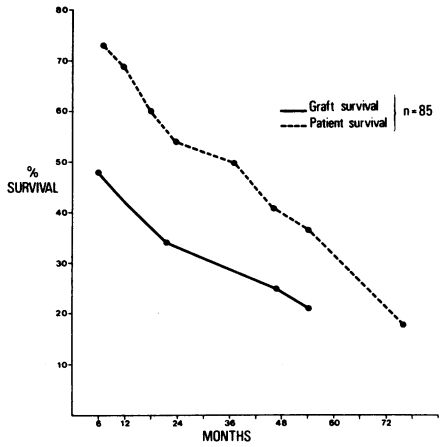

FIG. 4—Comparative survival of patients and grafts after first transplantation.

have been done at this centre, we combined patient and graft survival for all first transplants on one graph (Fig. 4). At 12 months following the first transplantation, graft survival was 42% and patient survival 69%. Only 13 patients received more than one graft; for this group graft and patient survival were 43% and 69%, respectively, at 1 year and 34% and 37% at 3 years. Reasons for failure of first grafts are detailed in Table V. In accord with most published data on results of transplantation the major cause of graft failure in this series was immunologic; the principal cause of the unusually high failure rate for transplantation from living donors at this centre was also immunologic.

Thirty-nine patients were trained for home dialysis. Seven died, but they had received modes of therapy other than in-centre hemodialysis and home hemodialysis (i.e., peritoneal dialysis and transplantation). No deaths occurred in the 17 patients treated only by in-centre and home hemodialysis, and the mean survival for this group was 33 months at the conclusion of this study.

Discussion

A developing interdependence of dialysis and transplantation was first recognized 5 years ago;[4,5] since then an integrated approach to therapy for end-stage renal disease has been advocated by other authors[6-8] and adopted by a number of centres.[7,9] Our results support the thesis that integrated treatment produces better results.

Table V—Reasons for failure of first graft

Reason	Source and no. of grafted kidneys: Cadaver (n = 71)	Living donor (n = 14)
Immunologic	20	5
Technical	3	1
Primary non-function	6	0
Death unrelated to transplantation	13	1
Vascular	2	2
Infection	3	0
Technical and vascular	1	0
Total	48	9

Survival in this series was better in patients treated by transplantation and dialysis than in patients treated by dialysis alone (with the exception of the patients who received only in-centre and home hemodialysis). It is difficult to discern the extent, in both this series and those reported by others, to which integrated therapy has been a deliberate choice rather than a *post hoc* description of changing techniques leading to longer patient survival. Refinements in dialysis techniques and the recognition that patients can receive more than one transplant have contributed to improved patient survival. An important factor leading to improved patient survival has been the recognition that in a patient whose kidney is being rejected immunosuppression should not be continued to the point beyond which it is difficult to re-establish dialysis.[10,11] In this series survival with hemodialysis alone was inferior to that reported by the European Dialysis and Transplantation Association in 1975.[12] However, we included all patients treated, even for a very short time, by dialysis. If patients treated for less than 3 months had been excluded from consideration, survival at 1 year would have been 73%.

The poor results of treatment by peritoneal dialysis alone and the relatively large number of deaths due to infection in this group of patients were in the early years of the program (1962-71), before a closed drainage system was introduced at this centre. Karanicolas and colleagues[13] recently reported more encouraging results with the use of peritoneal dialysis.

In contrast to the findings of Lowrie and associates[14] but in accord with the data reported by the United States National Dialysis Registry in 1972[15] and the European Dialysis and Transplantation Association,[12] survival in this series was better in patients undergoing home dialysis than in those undergoing in-centre dialysis. A study of our patients showed better overall rehabilitation in patients undergoing home dialysis than in those undergoing in-centre dialysis.[16] It is usually the more enterprising and socially stable patients who elect home dialysis, and we believe this partly accounts for their better survival.

The cost/benefit ratio and other economic factors in the treatment of end-stage renal disease have received much attention recently.[8,17] It has been suggested that equilibrium is achieved after 12 years when the number of deaths during treatment equals the number of new patients accepted for therapy. Our figures are strikingly similar to those predicted by Kerr,[17] although the admission rate for our centre, which serves approximately 1 million people, is slightly less (36 per million) than Kerr's. However, equilibrium has not yet occurred in this region, primarily because of a shortage of cadaver kidneys, and this has led to continued expansion of the dialysis program, particularly home dialysis.

We believe an integrated program should be pursued in the treatment of patients with end-stage renal disease. The extent of an integrated program, however, will vary with local circumstances, such as availability of cadaver kidneys, financial support for home and in-centre dialysis and the social conditions of each patient. It is only careful local adaptation to each of these factors that will allow optimum treatment of all patients with chronic renal failure.

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References

1. Snedecor GW, Cochran WG: *Statistical Methods,* 6th ed, Ames, IA, Iowa State U Pr, 1967
2. Gehan EA: A generalized two-sample Wilcoxon test for doubly censored data. *Biometrika* 52: 650, 1965
3. McLeod LE, Mandin H, Davidman M, et al: Intermittent hemodialysis in terminal chronic renal failure. *Can Med Assoc J* 94: 318, 1966
4. Gault MH, Dossetor JB: Kidney transplantation and long-term dialysis. *Am Heart J* 80: 439, 1970
5. Scribner BH: Emerging interrelationship between kidney transplantation and regular dialysis. *Transplant Proc* 3: 1395, 1971
6. Clunie GJA, Hartley LCJ, Ribush NT, et al: An integrated service for the treatment of irreversible renal failure. *Med J Aust* 2: 403, 1971
7. Matthew TH: Treatment of end-stage renal disease by integrated dialysis and transplantation. *Med J Aust* 2: 492, 1974
8. Burton BT: Chronic dialysis, USA — past, present and future. *Clin Nephrol* 3: 3, 1975
9. Farrow SC, Fisher DJ, Johnson DB: Dialysis and transplantation: the national picture over the next five years. *Br Med J* 3: 686, 1972
10. Wilson RE, Hume DM, Kizer W, et al: *Clinical Transplantation,* New York, Grune, 1973, p 323
11. Belzer FO, Kountz SL: The role of clinical transplantation in patients with end-stage renal disease. *Transplant Proc* 5: 793, 1973
12. Parsons FM, Brunner FP, Burck HC, et al: *Proceedings of the European Dialysis and Transplantation Association,* Moorhead JF, Baillod FA, Mion C (eds), London, Pitman Med, 1975, p 11
13. Karanicolas S, Oreopoulos DG, Pylypchuk G, et al: Home peritoneal dialysis: 3 years' experience in Toronto. *Can Med Assoc J* 116: 266, 1977
14. Lowrie EG, Lazarus JM, Mocelin AJ, et al: Survival of patients undergoing chronic hemodialysis and renal transplantation. *N Engl J Med* 288: 863, 1973
15. Bryan FA: National dialysis registry report, in *Fifth Annual Contractors' Conference of the Artificial Kidney Program of the National Institute of Arthritis and Metabolic Disease: Proceedings,* DHEW publ no (NIH) 72-248, Washington, 1972
16. Higgins MR, Bettcher KB, Harley FL, et al: Rehabilitation of patients treated by dialysis and transplantation. *Scand J Rehabil Med* 8: 107, 1976
17. Kerr DNS: Specific immunoglobulin for prevention of serum hepatitis (E). *Kidney Int* 3: 197, 1973